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Water Requirements of Cotton on Sandy Loam Soils in Southern San Joaquin Valley

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WATER REQUIREMENTS OF COTTON ON SANDY LOAM SOILS IN SOUTHERN SAN JOAQUIN VALLEY[1]

S. H. BECKETT[2] and CARROLL F. DUNSHEE[3]

INTRODUCTION

Cotton has been produced on a commercial scale in the San Joaquin Valley of California since 1918, when 1,100 acres of cotton was reported. In 1930, 270,000 acres was harvested; and cotton is now one of the major crops in the Valley.

Throughout the cotton-producing area of San Joaquin Valley, production depends almost entirely upon irrigation; and, because of wide variation in the soil types upon which the crop is grown, the irrigation problem is complex. Methods and practices of irrigation adapted to one locality may not necessarily apply to another locality where a different soil type predominates.

This bulletin presents the results of a five-year study dealing principally with the irrigation requirements of cotton grown on the sandy loam soils of the Delano series, and with the effects of soil-moisture deficiency on growth and yields.

The investigations described covered the years 1926 to 1930, inclusive, and were conducted at the United States Cotton Field Station at Shafter, California.[4]

[1] Received for publication May 10, 1932.

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[3] Assistant Crop Irrigationist in the Experiment Station; resigned June 30, 1929.

[4] During the first three and one-half years, the field work on which this report is based was in charge of Carroll F. Dunshee, who, with the senior author, organized the work and carried the responsibility of planning the experiments and successfully conducting them through that period. In 1929 and 1930 the field work was conducted by L. C. Schultz, Assistant Crop Irrigationist in the Experiment Station. The senior author has been associated with the study in an advisory capacity from the beginning. During 1926, 1927, and 1928, valuable advice and assistance in planning and carrying out the field and laboratory work were received from W. B. Camp, then Agronomist and Superintendent of the Cotton Field Station at Shafter. His successors, Fred W. Herbert and J. E. Hite, continued the splendid cooperation during the last two years of the investigations. John W. Carter, Assistant Scientific Aid; W. E. Clark, Junior Agronomist; and Joe F. Schuh, Assistant Scientific Aid, all of the Cotton Field Station, gave material help in the detailed field work of the experiments.

GENERAL DESCRIPTION OF THE AREA

Cotton growing in the San Joaquin Valley is confined principally to the six most southerly counties (Kern, Tulare, Kings, Madera, Fresno, and Merced), with a limited area in Stanislaus and San Joaquin counties. Of the 270,000 acres harvested in California in 1930, 88 per cent was in the San Joaquin Valley. However, the cotton acreage in California is less than 1 per cent of the total for the United States.

TABLE 1

AREA OF CROPPED LANDS AND AREA OF COTTON HARVESTED IN 1930 IN EACH OF THE COUNTIES IN THE COTTON-PRODUCING AREAS OF CALIFORNIA, WITH THE AVERAGE YIELDS PER ACRE AND THE GROSS PRODUCTION IN BALES

District or county	Area of cropped land*	Area of cotton harvested in 1930†	Average yield of cotton fiber per acre in 1930†	Gross production in 1930†
	acres	*acres*	*pounds*	*bales (500 pounds)*
Tulare County	316,900	63,400	484	64,090
Kern County	201,600	51,300	602	64,585
Fresno County	458,300	47,000	479	47,066
Madera County	83,300	26,800	450	25,200
Merced County	236,300	21,600	354	15,962
Kings County	138,000	25,200	532	28,012
San Joaquin and Stanislaus counties	675,300	2,900	217	1,316
Total, San Joaquin Valley	2,109,700	238,200	495	246,231
Palo Verde Valley	32,300	15,900	286	9,517
Coachella Valley	16,000	1,500	392	1,229
Total, Riverside County	.....	17,400	295	10,746
Imperial Valley	424,100	8,600	125	2,239
Bard area	5,100	5,800	375	4,541
Total, Imperial County	429,200	14,400	225	6,780
Total, California	.....	270,000	468	263,757

* Land classification by State Engineer, 1929.

† Report of California Cooperative Crop Reporting Service, 1930.

Table 1 shows the areas of cropped land and the areas of cotton harvested in the cotton-producing counties or districts in California in 1930, the average cotton yields per acre, and the gross production in bales.

Figure 1 shows the general location of the principal cotton-producing areas in the San Joaquin Valley.

Soil Types of the Area.—Throughout the cotton-producing areas of the San Joaquin Valley a wide variation in soil type is found, ranging from the light sandy loams and fine sandy loams of the Hanford, Delano, Fresno, and San Joaquin series to the extremely heavy clay adobes of the Stockton and Panoche series. Although

Fig. 1.—Location of the principal cotton-producing areas in the San Joaquin Valley, 1930. Each dot represents 1,000 acres.

information is not available for an accurate estimate of the cotton acreage on each of the soil types, a general survey of the area indicates that production on the sandier types amounts to at least 75 per cent of the total. In the Bakersfield, McFarland, Wasco, and Hanford areas, the Hanford and Delano fine sandy loams and sandy loams

are the most prominent. In the Madera and Fresno areas, the sandy loams and loams of the San Joaquin, Madera, Fresno, and Hanford series are the most common.

The heavier soil types upon which cotton is extensively grown are found in the lands bordering the Buena Vista and Tulare lake beds and in the area extending along the west side of the central part of the valley. In the Buena Vista and Tulare lake areas, the heavy soils are principally the loams, clay loams, and clays of the Tulare and Pond series. On the west side of the valley, including the Tranquillity, Firebaugh, and Dos Palos areas, the heavy types include the Stockton and Fresno loams and clay loams, the Merced clays, and the very heavy Stockton and Panoche clay adobes.

Water Supply.—The water supply for the cotton area of the San Joaquin Valley is obtained by gravity and by pumping. The principal gravity supplies come from the Kern, Kaweah, Kings, San Joaquin, and Merced rivers.

The principal pumped areas are found bordering Buena Vista and Tulare lakes in Kern and Kings counties; in the vicinity of Arvin, Shafter, McFarland, Wasco, and Delano in Kern County; in the Tulare and Tipton areas of Tulare County; and above the gravity canals on the west side of the valley in Fresno and Merced counties. Numerous pumping plants are also found in the areas generally covered by the gravity supplies. In practically all of the main pumped areas, the underground water level has been decidedly lowered from year to year.

Climate.—The climate is characterized by dry, hot summers and limited rainfall, practically all occurring between harvest and planting. The lower and flatter parts of the valley are most frequently visited by frosts, the usual frost period extending through the months of December, January, and February. The highest and lowest temperatures recorded in the cotton area of the San Joaquin Valley are 118° and 13° Fahrenheit. Temperatures of 105° to 110° F are not unusual.

Table 2 gives a comparison of temperatures and rainfall, and table 3 shows the general frost data at different points in the valley, both being taken from the annual summaries of the United States Weather Bureau.

TABLE 2

Annual Temperatures and Precipitation at Various Centers of the Cotton-Producing Areas of the San Joaquin Valley*

Locality	Length of record	Temperature			Seasonal rainfall		
		Maximum	Minimum	Mean	Maximum	Minimum	Average
	years	*°F*	*°F*	*°F*	*inches*	*inches*	*inches*
Bakersfield	33	118	13	64.6	9.30	2.77	5.71
Tulare	40	114	18	62.4	13.70	3.07	8.12
Fresno	41	115	17	63.0	19.45	4.96	9.82
Merced	50	116	16	62.2	22.08	3.20	11.17
Modesto	44	111	15	63.8	19.04	3.58	10.55
Hanford	23	113	14	61.6	12.51	5.57	8.77
Los Banos	39	110	20	.....	14.41	3.24	8.52

* U. S. Dept. Agr. Summary of climatological data for the United States. Section 14.—Central California.

TABLE 3

Dates of Killing Frosts and Length of Growing Season at Different Localities in the San Joaquin Valley*

Locality	Length of record	Average date of last killing frost in spring	Average date of first killing frost in autumn	Average length of growing season	Latest date of killing frost in spring	Earliest date of killing frost in autumn
	years			*days*		
Bakersfield	21	February 22	November 25	276	April 1	October 21
Tulare	12	March 13	November 18	250	April 11	October 20
Fresno	26	February 14	November 19	288	April 13	October 31
Merced	25	March 1	November 20	264	April 29	October 27
Modesto	14	February 1	December 5	307	March 1	November 11
Hanford	24	March 7	November 13	251	May 26	October 19
Los Banos	16	January 16	December 6	324	February 18	November 22

* U. S. Dept. Agr. Summary of climatological data for the United States. Section 14.—Central California.

DEFINITION OF TERMS

In presenting the results of these investigations, reference is frequently made to a number of terms used in irrigation practice. The most common of these are here defined:

Moisture percentage: the weight of water contained in a volume of soil, divided by the oven-dry weight of the soil and multiplied by 100. It is a comparison between the weight of water in a soil and the oven-dry weight of that soil.

Apparent specific gravity: the oven-dry weight of a volume of undisturbed soil divided by the weight of an equal volume of water.

Moisture equivalent: the amount of water retained in a soil against a centrifugal force 1,000 times gravity. It is expressed as a per-

centage of the oven-dry weight of the soil, and is a laboratory method of estimating the amount of water contained in the wetted portion of a soil.

Field capacity: the amount of water held in a soil against the force of gravity under unrestricted drainage. It is the moisture condition found in the wetted portion of the soil after an irrigation or rain and after removal of the free water by drainage.

Permanent wilting percentage:[5] the moisture percentage in the soil at which plants wilt and do not recover unless water is added to the soil. It is expressed in percentage of moisture based on the oven-dry weight of soil.

Temporary wilting percentage: the moisture percentage in the soil at which the leaves of the plant lose their turgidity for short periods of time, but revive without the application of water.

Efficiency of irrigation: the percentage of the water applied to the land that is accounted for in soil-moisture increase in the soil mass occupied by the principal rooting system of the plant.

Reduction of moisture percentages to acre-inches of water: in reducing moisture percentages to equivalent losses in acre-inches per acre, the formula $D = \frac{Pvd}{100}$ is used, where P represents the moisture percentage, v the apparent specific gravity of the soil (often referred to as the volume weight), d the depth of soil in inches, and D the equivalent depth of water in acre-inches per acre.

LOCATION OF EXPERIMENTAL PLOTS AND METHODS OF PROCEDURE

In starting the investigation reported herein, it was decided that more information of value could be obtained by an intensive study of the effects of variable irrigation treatments given to plots of limited areas than by less complete studies in commercial fields. The advantages of the smaller field plots are that they may be selected for uniformity in depth and type of soil; that they may be more evenly leveled; that water may be more evenly applied to them than to larger areas; and, finally, that they permit a more accurate record of seasonal soil-moisture conditions and fluctuations.

The work was centered at the United States Cotton Field Station at Shafter in Kern County because of the splendid facilities offered

[5] Veihmeyer, F. J., and A. H. Hendrickson. Essentials of irrigation and cultivation of orchards. California Agr. Ext. Cir. 50:1–24. 1930.

there. This station, located about 20 miles northwest of Bakersfield, is in one of the principal cotton-producing areas of the southern San Joaquin Valley.

The soil where the experimental plots were located is classed as a Delano sandy loam, typical of much of the plains area northwest and southeast of Bakersfield. Cotton is one of the principal crops produced in the area occupied by this soil type.

Delano sandy loam is grayish-brown and gritty, contains some mica, and is fairly uniform in texture to a depth of 5 feet. Below 5 feet is a layer of coarse sand of varying thickness. This type, though low in organic matter, is very fertile and easily cultivated, and takes water readily. Table 4 gives the principal characteristics of this soil as found at the Cotton Field Station.

TABLE 4

Characteristics of Delano Sandy Loams at United States Cotton Field Station on Which Plot Experiments Were Conducted

Depth of soil	Apparent specific gravity	Moisture equivalent	Observed field capacity	Permanent wilting percentage	Water-holding capacity between permanent wilting percentage and field capacity
		per cent	*per cent*	*per cent*	*acre-inches per acre-foot of soil*
First foot	1.42	10.11	.....	.....	.....
Second foot	1.50	8.78	.....	.....	.....
Third foot	1.53	10.36	.....	.....	.....
Fourth foot	1.55	10.52	.....	.....	.....
Fifth foot	1.51	9.08	.....	.....	.....
Sixth foot	1.47	5.85	.....	.....	.....
Average for first 5 feet	1.50	10.10	11.00	3.50	1.35

Irrigation water is obtained by pumping from two wells, one 12 inches and the other 14 inches in diameter. The pumps discharge into an earthen reservoir of about 1 acre-foot capacity. Distribution from this reservoir is made through a concrete-pipe system equipped with necessary gates and valves for constant-flow regulation.

Throughout the five years of the experiment, irrigation water was obtainable on demand and in any desired quantity.

Size of Plots.—During 1926, plots 40 feet wide and 300 feet long were used, each containing 9 rows of cotton spaced 48 inches apart. Beginning in 1927, however, the size of all plots was reduced to 16 by 90 feet, and the number of replications increased to nine for each of the major treatments. Four rows 48 inches apart were seeded in each plot, and the cotton was chopped to the same number of plants

in each row, with as nearly as possible an equal spacing of 12 inches between plants. In chopping, special care was taken to leave only normal plants. Soil samples, and all counts, measurements, and yield data were taken each year (including 1926) from the two middle rows of the plots, the outside rows being left as guards.

Fig. 2.—A field ditch and rectangular weirs used in delivering and measuring water to cotton plots.

Irrigation and Measurement of Water.—Water was delivered to each of the plots either directly from the concrete pipe line or from temporary field ditches. This arrangement permitted uniform application of any desired depth of water to the plots.

All water applied to the plots was measured through 1-foot rectangular weirs, installed in the field ditches extending along the upper

end of each tier of plots. Weir measurements of the flow were made at 5-minute intervals during the irrigation of each plot. Figure 2 shows a field ditch with weirs used in delivering and measuring water to the plots.

In each irrigation, including that given before planting, sufficient water was added to bring the soil in each plot to its full field capacity, to a depth of at least 5 feet.

Preparation of Seed Bed and Seeding.—Recognized good practices were used in preparing the seed bed and in seeding. Each year selected seed of the Acala variety was used, and a standard width of planting of 48 inches between rows was maintained. All plots were irrigated by flooding; and, while the plants were small, each irrigation was followed by a cultivation. As the season advanced, the size of the plants necessitated discontinuance of cultivation.

Where the condition of the cotton plant, as indicated by change in color of the foliage or wilting, was used as a basis for determining the time to irrigate, reliance was placed on the judgment of qualified authorities of the Cotton Field Station.

Soil Sampling and Computation.—Soil samples were taken on each plot to a depth of 5 feet before and after every irrigation, and a record was made of the quantity of water applied each time. Frequent measurements were also made of the average depth of moisture penetration when different depths of water were applied, and of the variation in depth of penetration through the length of the border checks.

All soil samples were taken with the improved soil tube.[6] In obtaining the soil samples, the top 3 inches of soil was removed, and the samples were taken from definitely established sampling points at 1-foot intervals, to a depth of 5 feet. Standard methods were used in weighing and drying the soil samples and in computation of moisture percentages. Soil samples were taken at the beginning and end of the season as well as before and after each irrigation. From the moisture percentages thus obtained, the amounts of water in acre-inches per acre from each foot of soil were computed by using the previously discussed formula $D = \frac{Pvd}{100}$; the total loss was then reduced to equivalent losses for 30-day periods. The method of calculation may perhaps be made clearer by showing the detailed steps in a particular case. To obtain the average rate of loss for treatment

[6] Veihmeyer, F. J. An improved soil sampling tube. Soil Science 27:147–152. 1929.

1, plot 23, from July 6 to July 14, for example, the average moisture content for each foot of depth on July 6 and July 14 is obtained from table 5, and the percentage loss and equivalent loss in acre-inches per acre calculated as shown in the accompanying table. The average rate of loss per 30 days can then be calculated from the total equivalent loss in acre-inches per acre from July 6 to July 14 (8 days): $\frac{2.56 \times 30}{8} = 9.60$ acre-inches per acre.

These losses were next plotted, and a consumptive use-of-water curve for the season was obtained. The average consumptive use of water for each month was then taken directly from the curve.

	First foot	Second foot	Third foot	Fourth foot	Fifth foot	Total
Average moisture content, July 6, per cent	10.2	9.6	10.7	11.9	10.4	.....
Average moisture content, July 14, per cent	5.4	5.8	7.8	9.2	10.3	.....
Loss, July 6 to July 14, per cent	4.8	3.8	2.9	2.7	0.1	.....
Average apparent specific gravity	1.50	1.50	1.50	1.50	1.50	.....
Equivalent loss, acre-inches per acre*	0.86	0.68	0.52	0.48	0.02	2.56

*Calculated for each foot by the formula $D = \frac{Pvd}{100}$; for the first foot this would be $\frac{4.8 \times 1.50 \times 12}{100} = 0.86$ acre-inch per acre.

PRELIMINARY OBSERVATIONS, SEASON OF 1926

The season of 1926 was spent in studying the effects of a limited number of treatments on plots at the Cotton Field Station, and in observing the results of different irrigation practices on commercial fields in the southern San Joaquin Valley.

Early in April, four border plots were set aside for these preliminary studies, and the following irrigation treatments were outlined:

Treatment A (duplicate plots): To be irrigated when the plants showed by their change from a light green to a dark bluish-green color that they were nearing the wilting stage. This treatment was expected to produce normal growth and yields.

Treatment B (single plot): To be irrigated when the plants showed definite indications of wilt at 4 P.M.

Treatment C (single plot): To be irrigated when the plants showed definite indications of wilt at 9 A.M. This is a more severe treatment than treatment B.

At different times during the season, counts were made of the shedding of the squares and of the number of bolls set on twelve representative plants under the 4 p.m. and 9 a.m. wilt treatments. At the end of the season, comparative yield records were obtained from these two plots.

Conclusions from Preliminary Observations.—All the growers interviewed, as well as those interested in investigational work in cotton production, believed proper irrigation to be one of the most important factors affecting the yield and the quality of the product. The field observations and plot studies in 1926 led to the following conclusions:

1. Cotton is sensitive to soil-moisture fluctuations; one of the causes of excessive shedding of the squares is unfavorable soil-moisture conditions.

2. The average yield of cotton in the upper San Joaquin Valley was reduced by an amount estimated at from 10 to 15 per cent because of improper irrigation in the latter part of the season.

3. Poor preparation of land for irrigation very often accounts for the "spotted" condition of growth and yields.

4. Where the water is limited, there is a tendency to serve too large an acreage with the supply at hand.

The Delano sandy loams at the Shafter Station have a field capacity of about 11 per cent and a temporary wilting percentage of from 4.0 to 4.5 per cent. Permanent wilting occurred at 3.5 per cent.

With the soil at the permanent wilting percentage, 1.35 acre-inches of water per acre was required to bring 1 foot depth of soil to its field capacity.

A definite difference was shown in shedding, number of bolls, and yields in the plots irrigated when the plants wilted at 4 p.m. and at 9 a.m. The 4 p.m.-wilt plots had 11.3 per cent less shedding, produced 13.7 per cent more bolls, and yielded 15 per cent more cotton.

FIELD-PLOT INVESTIGATIONS DURING 1927, 1928, 1929, AND 1930

After the preliminary observations of 1926, the investigations were limited to field plots and to tanks located at the Cotton Field Station at Shafter. The tank layout and the procedure and results obtained are discussed in a later section of this bulletin.

From 1927 to 1930 the method of measuring the amounts of water applied to the plots, the preparation of the seed bed, the selection of seed, and the seeding, were substantially the same as during 1926.

In each of the four years the following irrigation treatments were given:

Treatment 1: Irrigated when the average moisture content of the top 5 feet of soil reached approximately 7 per cent. This is about halfway between field capacity and the permanent wilting percentage. It was anticipated that if the average moisture content were maintained above this figure, readily available moisture would be present in the entire soil depth throughout the season, and that at no time during the season would the plants show indications of approaching the wilting stage.

Treatment 2: Irrigated when the plants wilted at 4 P.M. Mid-afternoon wilt shows a lack of available moisture in the soil; a change in color of the foliage from a light green to a dark bluish-green indicates that the plants are approaching wilting.

Treatment 3: Irrigated when the plants wilted at 9 A.M. Early-morning wilt was considered to indicate definite distress in the plant resulting from a lack of soil moisture.

Treatment 4: Irrigated as in treatment 1 until midseason (about July 20), after which water was not applied until the plants wilted at 9 A.M. It was anticipated that in this treatment an abundance of soil moisture would be available during the first half of the season, with a definite deficiency during the last half.

Treatment 5: Irrigated during the first half of the season (until about July 20) when the plants wilted at 9 A.M., as in treatment 3, after which it was irrigated as in treatment 1. Treatment 5 thus provided for a deficiency in available moisture during the first half of the season and no deficiency during the second half.

Treatment 1A: In this treatment, introduced during the 1930 season, water was added when the plants changed from a light green to a dark bluish-green color. This change in color usually occurs several days in advance of wilting and is the first indication given by the plant of soil-moisture shortage. The total depth of water applied during the season was intermediate between the amounts applied in treatments 1 and 2.

Treatment 1AA: This, the second new treatment added in 1930, was planned as an intermediate treatment between 1 and 1A, with the water applied when the moisture content of the soil, to a depth of 5 feet, had reached an average of 5.5 to 6.0 per cent.

Figure 3 shows the general arrangement of the plots with the plot number and irrigation treatment. Substantially this same arrange-

ment was followed during 1927, 1928, 1929, and 1930. This arrangement provided for nine replications of treatments 1 and 2, eight of treatment 3, and five of treatments 4 and 5. In 1930 five new plots were added to take care of treatment 1A, and four for treatment 1AA.

Waste check 26		Waste check 13		Tank Yard	
⑤	27	④	14	①	1
④	28	①	15	②	2
①	29	②	16	③	3
②	30	③	17	⑤	4
③	31	④ ✳	18	①	5
④	32	① ✳	19	②	6
①	33	② ✳	20	③	7
②	34	③ ✳	21	④	8
③	35	⑤ ✳	22	①	9
⑤	36	① ✳	23	②	10
①	37	② ✳	24	③	11
②	38	③ ✳	25	⑤	12

weir

weir

Fig. 3.—Arrangement of field plots, delivery ditches, and weirs, 1927, 1928, and 1929. The stars indicate plots in which soil samples were taken. The treatments, indicated by the numbers in circles, were as follows: (1) irrigated when moisture content reached about 7 per cent; (2) irrigated when plants wilted at 4 P.M.; (3) irrigated when plants wilted at 9 A.M.; (4) high moisture content early in season, low last half of season; (5) low moisture content early in season, high last half of season.

Results of Soil-Moisture Observations.—Throughout each of the four seasons, soil samples were taken to a depth of 5 feet before and after each irrigation at four fixed locations in duplicate plots under treatments 1, 2, and 3, and in single plots under treatments 4 and 5, as well as from duplicate plots in treatment 1A during 1930.

The methods of summarizing the data collected are illustrated in tables 5 and 6. Table 5 summarizes the average moisture content of plot 23 at each sampling, with the dates and quantities of irrigation water applied to it during 1927. In table 6 the moisture percentages obtained from plots 19 and 23 (both given treatment 1) have been reduced to acre-inches of water per acre taken by the growing crop from each foot in depth of soil; similar data were obtained from each of the plots sampled during the four-year period. Soil-moisture determinations were made on approximately 3,000 samples each year. Tables 7 to 10 show the rates of use of water in the intervals between irrigations for each treatment during each of the four years, calculated from the moisture percentages found.

TABLE 5

AVERAGE MOISTURE CONTENT AND DATES AND AMOUNTS OF IRRIGATION FOR TREATMENT 1, PLOT 23; MAY 11 TO NOVEMBER 1, 1927

Dates of sampling	Average moisture content of soil					Dates of irrigation	Amount of irrigation water applied
	First foot	Second foot	Third foot	Fourth foot	Fifth foot		
	per cent	*per cent*	*per cent*	*per cent*	*per cent*		*acre-inches per acre*
May 11	8.1	8.0	9.5	9.2	9.1		
June 2	6.2	7.7	9.3	10.1	9.2	June 2	4
June 6	10.2	10.0	11.0	11.3	9.3		
June 21	6.3	8.5	9.8	10.3	9.2	June 22	3
June 24	10.6	10 8	11.5	11.6	10.4		
July 2	6.1	7.4	9.7	10.0	10.1	July 4	3
July 6	10.2	9.6	10.7	11.9	10.4		
July 14*	5.4	5.8	7.8	9.2	10.3	July 15	4
July 18	9.4	9.1	9.7	9.2	9.4		
July 25	5.2	4.7	6.4	8.1	9.1	July 26	5
July 28	10.9	10.4	9.8	9.2	8.7		
August 9	5.2	4.7	5.5	6.7	7.1	August 9	5
August 12	9.8	9.4	9.8	9.2	7.5		
August 23	5.4	5.3	5.7	6.6	6.2	August 25	5
August 27	10.8	9.4	7.5	6.6	5.9		
September 13	5.4	5.1	5.2	4.8	4.8	September 14	5
September 16	10.7	10.1	10.0	5.8	4.3		
September 29	6.8	7.2	7.3	6.7	4.6	September 30	4
October 3	11.0	10.4	10.8	10.5	8.5		
November 1*	10.7	6.7	7.7	8.1	7.1		
Total	.....	.....	.....	.....	.....		38

* 1.35 inches of rain on October 29 and 30.

TABLE 6

Quantities of Water Used in Intervals Between Irrigations on Treatment 1, Plots 19 and 23; April 10 to November 1, 1927

Interval	Number of days	Soil-moisture loss, acre-inches per acre						
		First foot	Second foot	Third foot	Fourth foot	Fifth foot	Total	Equivalent loss in 30 days
Plot 19								
April 10 to May 11	31	0.25	0.11	0.11	0 09	0.11	0.67	0.65
May 11 to June 2	22	0.25	0.11	0.09	0.11	0.14	0.70	0.95
June 6 to June 21	15	0.88	0.65	0.18	0.31	0.12	2.14	4.28
June 24 to July 2	8	0.90	0.61	0.41	0.20	0.14	2.26	8.46
July 6 to July 14	8	0.94	0.79	0.50	0.31	0.38	2.92	10.95
July 18 to July 25	7	0.70	0.63	0.70	0.20	0.31	2.54	10.90
July 28 to August 9	12	1.06	0.77	0.75	0.61	0.70	3.89	9.70
August 12 to August 23	11	0.90	0.68	0.66	0.56	0.23	3.03	8.26
August 27 to September 13	17	0.86	0.88	0.74	0.40	0.18	3.06	5.40
September 16 to September 29	13	0.70	0.48	0.36	0.27	.....	1.81	4.18
October 3 to November 1	29	0.82	0.68	0.49	0.61	0.47	3.07	3.18
Plot 23								
May 11 to June 2	22	0.34	0.06	0.04	.....	.....	0.44	0.60
June 6 to June 21	15	0.70	0.27	0.22	0.18	0.02	1.39	2.78
June 24 to July 2	8	0.81	0.61	0.32	0.29	0.05	2.08	7.80
July 6 to July 14	8	0.86	0.68	0.52	0.48	0.02	2.56	9.60
July 18 to July 25	7	0.76	0.79	0.60	0.20	0.05	2.40	10.30
July 28 to August 9	12	1.03	1.03	0.77	0.45	0.29	3.57	8.92
August 12 to August 23	11	0.79	0.74	0.74	0.47	0.23	2.97	8.10
August 27 to September 13	17	0.97	0.77	0.41	0.32	0.20	2.67	4.71
September 16 to September 29	13	0.70	0.52	0.48	.....	.....	1.70	3.92
October 3 to November 1	29	0.85	0.67	0.56	0.43	0.25	2.76	2.86

TABLE 7

RATES OF USE OF WATER IN INTERVALS BETWEEN IRRIGATIONS IN TREATMENTS 2, 3, 4, AND 5; SEASON OF 1927

Interval	Number of days	Acre-inches per acre: Soil-moisture loss	Acre-inches per acre: Equivalent loss in 30 days	Interval	Number of days	Acre-inches per acre: Soil-moisture loss	Acre-inches per acre: Equivalent loss in 30 days
Treatment 2							
Plot 20				**Plot 24**			
April 10 to May 11	31	0.57	0.55				
May 11 to June 2	22	0.49	0.67	May 11 to June 2	22	0.67	0.91
June 9 to July 8	29	3.63	3.75	June 9 to July 8	29	3.46	3.58
July 13 to July 26	13	3.59	8.28	July 11 to July 21	10	2.16	6.48
July 28 to Aug. 18	21	4.92	7.03	July 23 to Aug. 1	19	3.91	6.18
Aug. 20 to Sept. 1	12	2.24	5.60	Aug. 19 to Sept. 3	15	1.65	3.30
Sept. 3 to Sept. 26	23	3.35	4.37	Sept. 6 to Sept. 27	21	3.53	5.02
Sept. 29 to Nov. 1	33	2.46	2.24	Oct. 1 to Nov. 1	31	2.23	2.16
Treatment 3							
Plot 21				**Plot 25**			
April 10 to May 11	31	0.61	0.59				
May 11 to June 2	22	0.67	0.91	May 11 to June 2	22	0.77	1.05
June 9 to July 15	36	5.13	4.28	June 9 to July 15	36	4.79	4.00
July 18 to Aug. 6	19	4.08	6.44	July 18 to Aug. 6	19	3.45	5.45
Aug. 9 to Aug. 30	21	4.34	6.20	Aug. 9 to Aug. 27	18	3.42	5.60
Sept. 2 to Sept. 27	25	3.24	3.89	Aug. 30 to Sept. 27	28	3.35	3.59
Oct. 1 to Nov. 1	31	2.93	2.84	Oct. 1 to Nov. 1	31	1.84	1.78
Treatment 4, plot 18				**Treatment 5, plot 22**			
April 10 to May 11	31	0.56	0.54				
May 11 to June 2	22	0.97	1.32	May 11 to June 2	22	0.59	0.80
June 6 to June 22	16	2.40	4.50	June 2 to June 21	19	0.87	1.37
June 25 to July 8	13	2.42	5.58	June 25 to July 18	23	5.09	6.64
July 11 to July 20	9	2.84	9.46	July 20 to Aug. 12	23	4.35	5.68
July 23 to Aug. 17	25	5.76	6.90	Aug. 16 to Aug. 27	11	2.55	6.95
Sept. 6 to Sept. 26	20	2.29	3.43	Aug. 30 to Sept. 15	16	2.19	4.10
Sept. 29 to Nov. 1	33	2.33	2.12	Sept. 15 to Oct. 10	25	1.67	2.01
				Oct. 14 to Nov. 1	18	1.92	3.20

TABLE 8

Rates of Use of Water in Intervals Between Irrigations in Treatments 1, 2, 3, 4, and 5; Season of 1928

Interval	Number of days	Acre-inches per acre		Interval	Number of days	Acre-inches per acre	
		Soil-moisture loss	Equivalent loss in 30 days			Soil-moisture loss	Equivalent loss in 30 days
Treatment 1, plots 22 and 26				Treatment 2, plots 23 and 27			
April 19 to June 6	48	1.09	0.68	April 19 to June 6	48	1.22	0.76
June 11 to July 2	21	3.37	4.82	June 6 to July 6	30	2.76	2.76
July 6 to July 14	8	1.69	6.34	July 10 to July 23	13	2.58	5.95
July 19 to July 26	7	1.68	7.21	July 28 to Aug. 9	12	3.36	8.42
July 28 to Aug. 6	9	3.03	10.10	Aug. 13 to Aug. 27	13	2.10	4.85
Aug. 9 to Aug. 17	8	1.98	7.44	Sept. 3 to Nov. 1	59	5.26	2.68
Aug. 20 to Aug. 29	9	1.97	6.57				
Sept. 4 to Sept. 11	7	1.28	5.50				
Sept. 17 to Oct. 15	28	3.68	3.92				
Oct. 18 to Nov. 1	14	1.84	3.92				
Treatment 3, plots 24 and 28				Treatment 4, plot 21			
April 19 to June 6	48	1.18	0.74	April 19 to June 6	48	1.44	0.90
June 6 to July 15	39	3.40	2.62	June 11 to July 2	21	3.41	4.87
July 21 to Aug. 14	24	5.35	6.69	July 6 to July 14	8	2.23	8.35
Aug. 17 to Sept. 7	21	4.08	5.83	July 19 to Aug. 3	15	3.04	6.08
Sept. 10 to Oct. 16	36	2.85	2.38	Aug. 7 to Aug. 20	13	2.12	4.89
Oct. 19 to Nov. 1	13	0.95	2.19	Aug. 24 to Sept. 14	21	4.27	6.10
				Sept. 20 to Nov. 1	42	2.92	2.08
Treatment 5, plot 26							
April 19 to June 6	48	1.09	0.68				
June 6 to July 15	39	3.61	2.78				
July 21 to July 30	9	2.00	6.67				
July 31 to Aug. 11	11	3.60	9.82				
Aug. 15 to Aug. 22	7	1.79	7.65				
Aug. 25 to Sept. 4	10	2.09	6.27				
Sept. 22 to Oct. 13	21	3.52	5.01				
Oct. 18 to Nov. 1	14	1.79	3.84				

TABLE 9

RATES OF USE OF WATER IN INTERVALS BETWEEN IRRIGATIONS IN TREATMENTS 1, 2, 3, 4, AND 5; SEASON OF 1929

Interval	Number of days	Acre-inches per acre	
		Soil-moisture loss	Equivalent loss in 30 days
Treatment 1, plots 22 and 26			
April 10 to June 5	56	2.02	1.08
June 6 to June 25	19	0.82	1.29
June 28 to July 13	15	3.06	6.12
July 19 to July 27	8	1.98	7.42
Aug. 1 to Aug. 13	12	4.13	10.31
Aug. 17 to Aug. 27	10	3.78	11.35
Aug. 31 to Sept. 14	14	3.50	7.50
Sept. 19 to Nov. 1	43	4.14	2.89
Treatment 2, plots 23 and 27			
April 10 to June 5	56	2.43	1.30
June 6 to July 17	41	2.65	1.94
July 20 to Aug. 13	24	4.36	5.45
Aug. 17 to Sept. 10	24	3.38	4.24
Sept. 13 to Nov. 1	49	4.72	2.89
Treatment 3, plots 24 and 28			
April 10 to June 5	56	2.63	1.41
June 6 to July 27	51	3.81	2.24
Aug. 2 to Sept. 3	32	4.69	4.40
Sept. 7 to Nov. 1	55	5.38	2.93
Treatment 4, plot 21			
April 10 to June 5	56	2.02	1.08
June 6 to June 24	18	1.22	2.03
June 28 to July 13	15	2.49	4.98
July 19 to July 27	8	2.39	8.97
July 28 to Aug. 12	15	2.79	5.58
Aug. 16 to Sept. 3	18	3.29	5.48
Sept. 7 to Nov. 1	55	5.92	3.26
Treatment 5, plot 25			
April 10 to June 5	56	2.56	1.37
June 6 to July 27	51	5.57	3.28
Aug. 1 to Aug. 15	14	3.06	6.55
Aug. 20 to Sept. 3	14	2.99	6.51
Sept. 7 to Sept. 24	17	3.44	6.07
Sept. 28 to Nov. 1	34	4.54	4.01

TABLE 10

Rates of Use of Water in Intervals Between Irrigations in Treatments 1, 1a, 2, 3, 4, and 5; Season of 1930

Interval	Number of days	Acre-inches per acre		Interval	Number of days	Acre-inches per acre	
		Soil-moisture loss	Equivalent loss in 30 days			Soil-moisture loss	Equivalent loss in 30 days
Treatment 1, plots 22 and 26				Treatment 1A, plots 20 and 29			
April 12 to May 22	40	1.16	0.87	April 12 to May 22	40	1.56	1.17
May 23 to June 21	29	1.44	1.49	May 23 to June 21	29	1.78	1.84
June 24 to July 16	22	3.86	5.26	June 21 to July 16	25	2.25	2.70
July 21 to July 31	10	2.50	7.50	July 21 to Aug. 5	15	3.00	6.00
Aug. 4 to Aug. 15	11	3.14	8.56	Aug. 9 to Aug. 26	17	4.02	7.10
Aug. 18 to Aug. 25	7	2.20	9.42	Aug. 29 to Sept. 22	24	3.78	4.70
Sept. 1 to Sept. 14	14	2.78	5.95	Sept. 26 to Oct. 13	17	2.60	4.59
Sept. 19 to Sept. 30	11	2.04	5.55	Oct. 13 to Nov. 1	19	1.39	2.18
Oct. 1 to Nov. 1	31	1 84	1.78				
Treatment 2, plots 23 and 27				Treatment 3, plots 24 and 28			
April 12 to May 22	40	1.04	0.78	April 12 to May 22	40	1.00	0.75
May 23 to July 1	38	2.00	1.57	May 23 to July 1	38	2.30	1.82
July 2 to July 21	19	1.64	2.58	July 2 to July 16	14	1.32	2.82
July 25 to Aug. 14	20	3.46	5.19	July 17 to Aug. 20	34	4.30	3.80
Aug. 18 to Sept. 15	28	4.53	4.85	Aug. 25 to Sept. 9	15	2.25	4.50
Sept. 23 to Oct. 13	20	2.20	3.30	Sept. 12 to Sept. 30	18	2.37	3.95
Oct. 14 to Nov. 1	18	0.96	1.60	Oct. 1 to Oct. 13	12	0.53	1.32
				Oct. 14 to Nov. 1	18	0.75	1.25
Treatment 4, plot 21				Treatment 5, plot 25			
April 12 to May 22	40	0.88	0.66	April 12 to May 22	40	1.07	0.80
May 23 to June 21	29	1.34	1.39	May 23 to June 11	19	1.22	1.93
June 24 to July 16	22	3.97	5.42	June 12 to July 1	19	0.95	1.50
July 21 to July 31	10	2.50	7.50	July 2 to July 16	14	0.87	1.86
Aug. 1 to Aug. 14	13	2.00	4.61	July 17 to July 30	13	0.79	1.82
Aug. 18 to Sept. 15	28	5.16	5.52	Aug. 2 to Aug. 15	13	2.41	5.56
Sept. 22 to Oct. 13	21	2.02	2.89	Aug. 18 to Sept. 4	17	3.39	5.98
Oct. 14 to Nov. 1	18	1.22	2.03	Sept. 9 to Sept. 22	13	2.43	5.60
				Sept. 26 to Oct. 13	17	2.82	4.98
				Oct. 14 to Nov. 1	18	1.30	2.17

Figures 4, 5, and 6 show by means of diagrams the seasonal variation in moisture content of the soil in the plots under treatments 1, 2, and 3 in 1927. Similar diagrams were prepared for each plot from which soil samples were taken during the other three years; they are not included here because those for 1927 are typical of the others.

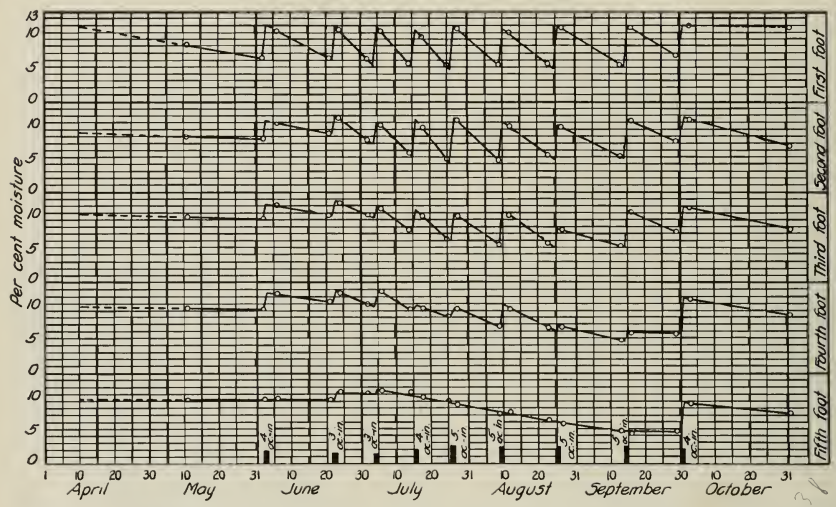


Fig. 4.—Seasonal variation in moisture content of continuously moist cotton irrigation plot, treatment 1, plot 23, season of 1927. Solid bars at bottom indicate irrigations.

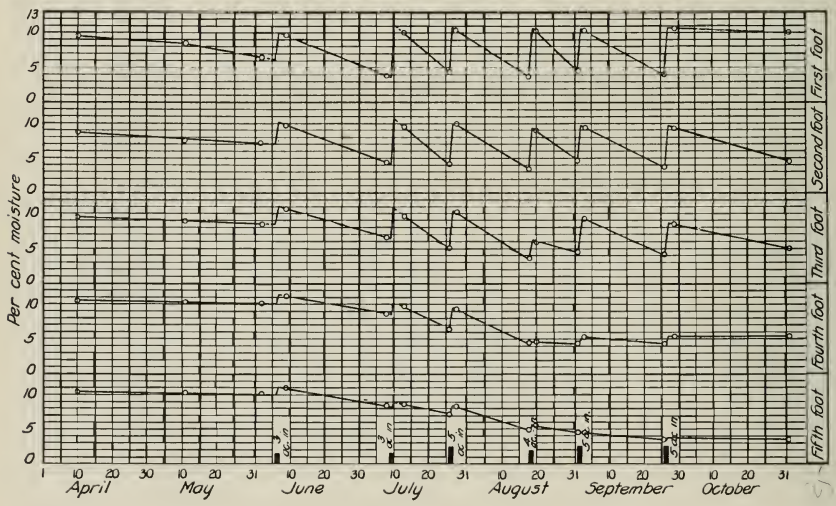


Fig. 5.—Seasonal variation in moisture content of cotton plot irrigated when plants wilted at 4 P.M., treatment 2, plot 20, season of 1927. Solid bars at bottom indicate irrigations.

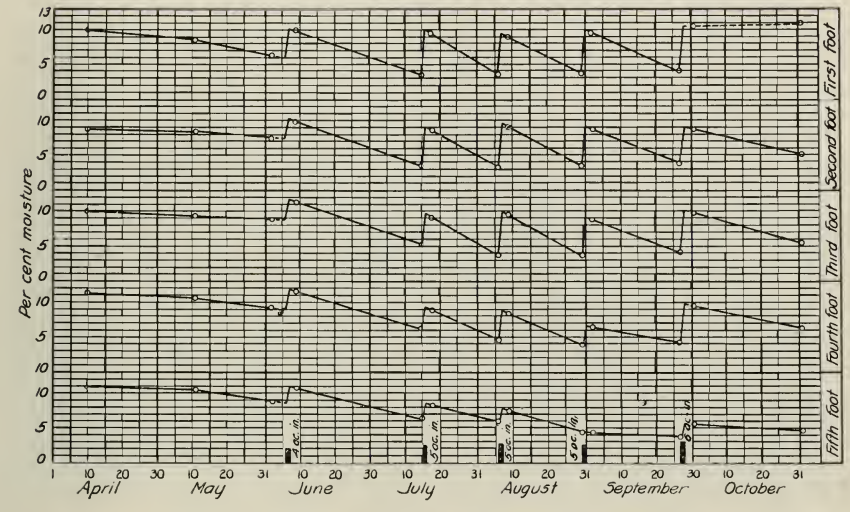
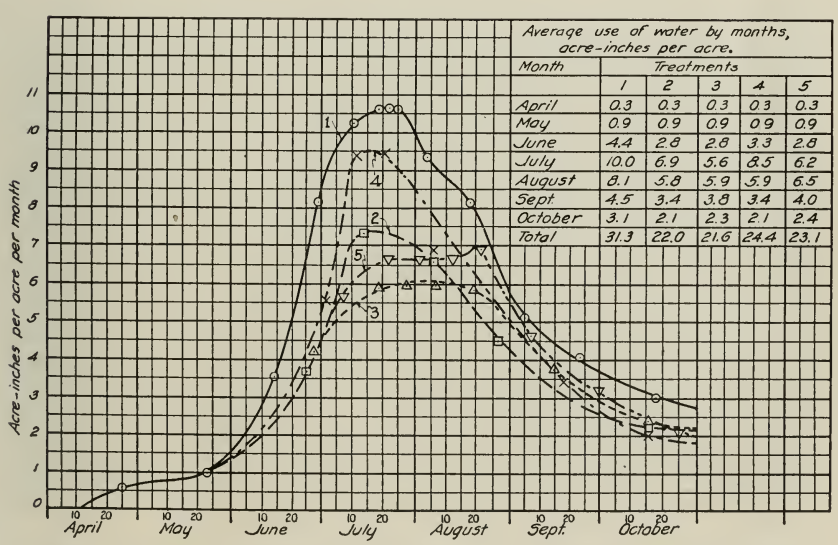


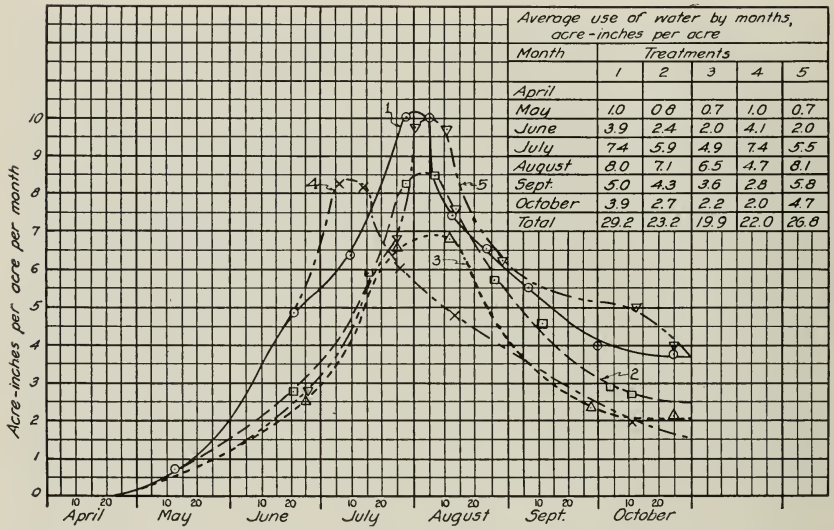
Fig. 6.—Seasonal variation in moisture content of cotton plot irrigated when the plants wilted at 9 A.M., treatment 3, plot 21, season of 1927. Solid bars at bottom indicate irrigations.



Average use of water by months, acre-inches per acre.

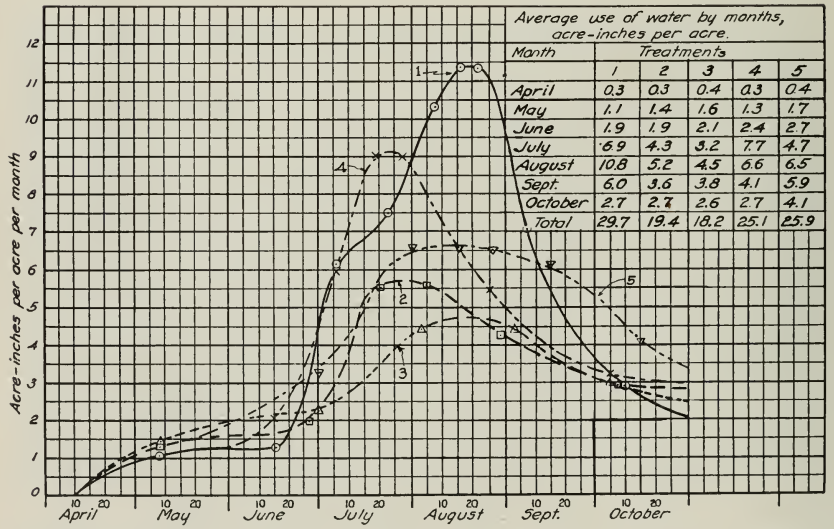
Month	Treatments				
	1	2	3	4	5
April	0.3	0.3	0.3	0.3	0.3
May	0.9	0.9	0.9	0.9	0.9
June	4.4	2.8	2.8	3.3	2.8
July	10.0	6.9	5.6	8.5	6.2
August	8.1	5.8	5.9	5.9	6.5
Sept.	4.5	3.4	3.8	3.4	4.0
October	3.1	2.1	2.3	2.1	2.4
Total	31.3	22.0	21.6	24.4	23.1

Fig. 7.—Average seasonal use of water in acre-inches per acre per month, irrigation treatments 1, 2, 3, 4, and 5, season of 1927.



Month	Treatments				
	1	2	3	4	5
April					
May	1.0	0.8	0.7	1.0	0.7
June	3.9	2.4	2.0	4.1	2.0
July	7.4	5.9	4.9	7.4	5.5
August	8.0	7.1	6.5	4.7	8.1
Sept.	5.0	4.3	3.6	2.8	5.8
October	3.9	2.7	2.2	2.0	4.7
Total	29.2	23.2	19.9	22.0	26.8

Fig. 8.—Average seasonal use of water in acre-inches per acre per month, irrigation treatments 1, 2, 3, 4, and 5, season of 1928.



Month	Treatments				
	1	2	3	4	5
April	0.3	0.3	0.4	0.3	0.4
May	1.1	1.4	1.6	1.3	1.7
June	1.9	1.9	2.1	2.4	2.7
July	6.9	4.3	3.2	7.7	4.7
August	10.8	5.2	4.5	6.6	6.5
Sept.	6.0	3.6	3.8	4.1	5.9
October	2.7	2.7	2.6	2.7	4.1
Total	29.7	19.4	18.2	25.1	25.9

Fig. 9.—Average seasonal use of water in acre-inches per acre per month, irrigation treatments 1, 2, 3, 4, and 5, season of 1929.

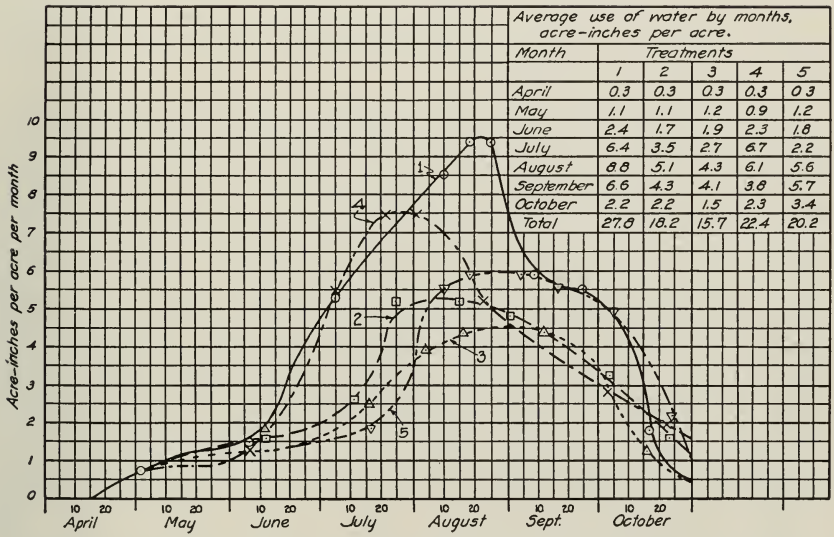


Fig. 10.—Average seasonal use of water in acre-inches per acre per month, irrigation treatments 1, 2, 3, 4, and 5, season of 1930.

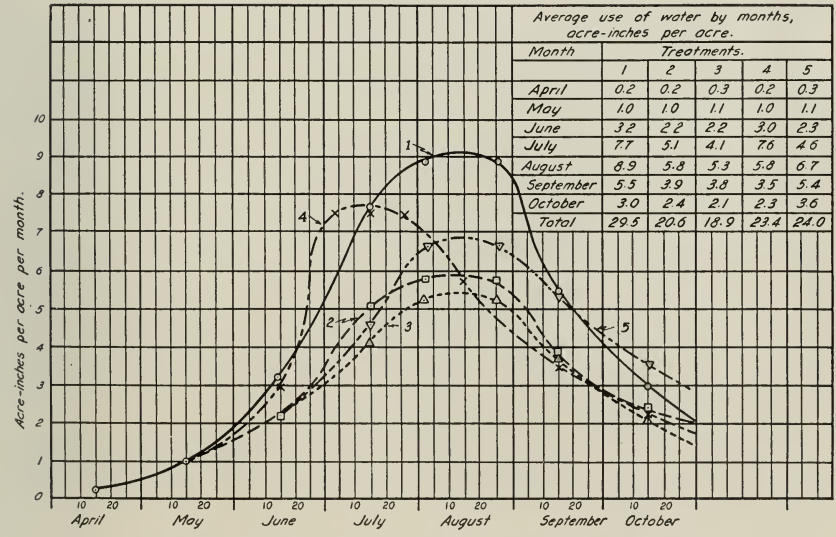


Fig. 11.—Average seasonal use of water in acre-inches per acre per month, irrigation treatments 1, 2, 3, 4, and 5, 1927 to 1930.

In figures 7, 8, 9, and 10, the data shown in tables 6 to 10 have been plotted as seasonal-use-of-water curves from which the average use of water in acre-inches per acre per month for each treatment is obtained. Figure 11, a composite diagram, shows the average use of water during the four years.

These diagrams show that under treatment 1, the use of water by the crop reached its peak during the latter part of July in 1927 and 1928 and about the middle of August in 1929 and 1930, and that during these periods of maximum use, the crop was using water from the soil at the rate of 10.5 acre-inches per acre per month. These periods of maximum use of water are of comparatively short duration and occur at the peak of the flowering period, rather than at the period of maximum temperatures. With the exception of treatment 5, under which a heavy vegetative growth was produced late in the season, the decline in the use of water after the peak of the flowering period was very rapid. In treatments 1 to 4, the September use averaged 65 per cent of that in August, while the October use was 57 per cent of that in September.

Table 11 shows the average moisture content of the soil in each treatment at the time of irrigation.

The results in this table show comparatively small differences in average moisture content of the top 5 feet of soil among plots irrigated when the plants wilted at 9 A.M. or 4 P.M., or when they showed their first indication of lack of moisture by their change in color.

The first indication of wilt as shown in treatment 2 occurs when the moisture in the top foot of soil has been reduced to a point slightly above the permanent wilting percentage. At this time the second and third feet average about 1 per cent and the fourth and fifth feet, 2 per cent moisture above the permanent wilting percentage. Early-morning wilt as shown in treatment 3, occurred when the top 2 feet of soil had reached the permanent wilting percentage, with the third, fourth, and fifth feet averaging only 1 per cent above it. According to one year's observations, the change in color of foliage due to soil moisture shortage apparently occurs when the top 2 feet is 1 per cent above the permanent wilting percentage, but while readily available moisture is still present in the lower depths.

Seasonal Use of Water by Cotton.—The average use of water by months and the irrigation data for each of the treatments are given in tables 12 and 13.

TABLE 11

Average Moisture Content of the Soil in Each Treatment at the Time of Irrigation

Season	Per cent moisture					
	First foot	Second foot	Third foot	Fourth foot	Fifth foot	Average
Treatment 1						
1927	5.4	5.9	7.0	8.3	7.8	6.9
1928	6.0	6.4	7.2	7.9	7.5	7.0
1929	5.3	5.9	7.1	8.8	8.3	7.1
1930	5.0	6.0	7.1	8.6	8.1	7.0
Average	5.4	6.0	7.1	8.4	7.9	7.0
Treatment 2						
1927	4.5	4.5	5.2	6.0	5.9	5.2
1928	3.9	4.4	4.6	5.3	5.0	4.6
1929	3.8	4.4	4.7	5.4	5.6	4.8
1930	3.9	4.6	4.9	5.5	5.3	4.8
Average	4.0	4.5	4.8	5.6	5.4	4.8
Treatment 3						
1927	3.7	3.6	4.3	4.5	4.2	4.1
1928	3.4	3.9	4.1	4.4	4.1	4.0
1929	3.2	3.6	3.8	4.4	5.5	4.1
1930	3.2	4.3	4.5	4.9	4.9	4.4
Average	3.4	3.8	4.2	4.6	4.7	4.2
Treatment 1A						
1930	4.0	4.7	5.2	6.4	6.1	5.3

TABLE 12

Average Use of Water by Months, Seasons 1927 to 1930

Treatment	Average use, in acre-inches per acre							
	April	May	June	July	Aug.	Sept.	Oct.	Total
1	0.2	1.0	3.2	7.7	8.9	5.5	3.0	29.5
2	0.2	1.0	2.2	5.1	5.8	3.9	2.4	20.6
3	0.3	1.1	2.2	4.1	5.3	3.8	2.1	18.9
4	0.2	1.0	3.0	7.6	5.8	3.5	2.3	23.4
5	0.3	1.1	2.3	4.6	6.7	5.4	3.6	24.0

As would be expected, treatment 1, with the moisture supply above the permanent wilting percentage throughout the season, showed the greatest use of water, averaging 29.5 acre-inches per acre for the four years. This figure was 43 per cent greater than the use under treatment 2, 55 per cent greater than under treatment 3, 28 per cent greater than under treatment 4, and 23 per cent greater than under treatment 5.

Table 13 shows that an average of 72.8 per cent of the water applied during the growing season was accounted for in soil-moisture increase in the top 5 feet of soil and that 83.5 per cent of the total amount of water applied during the season was used through transpiration in producing the crop.

TABLE 13

SUMMARY OF IRRIGATION DATA; AVERAGES FOR SEASONS 1927 TO 1930

Treatment	Number of irrigations	Amount of water, in acre-inches per acre				Per cent	
		Total applied	Total applied during growing season	Accounted for in soil-moisture increase*	Used by the crop	Efficiency of irrigation*	Water applied which was used by the plants
1	7	38.6	32.6	22.6	29.5	69.4	76.5
2	4	24.8	18.8	14.2	20.6	75.5	83.0
3	3	22.6	16.6	12.5	18.9	75.4	83.7
4	5	28.0	22.0	15.5	23.1	70.5	82.5
5	5	26.2	26.2	19.0	24.0	72.6	91.7
Average	.....	.....	.....	.....	.....	72.8	83.5

* For the amounts of water applied during the growing season.

Growth and Yield.—During each of the four years, the growth (as measured by the height of plants, flowering characteristics, percentage of shedding, number of bolls, yield, lint index, length of staple) under the different treatments followed so nearly the same trend that publishing of the detailed results for each year is not considered necessary.

Effect of Irrigation on Size of Plants.—The average height of plants produced each year under the different treatments is shown in table 14.

This table shows that as an average over the four-year period, the same height of plant was obtained when the plants were allowed to wilt at 9 A.M. early in the season, but with moisture available continuously after August 1 (treatment 5), as was obtained when available moisture was present throughout the season (treatment 1). During the fall of the year the plants under treatment 5 were making the

growth ordinarily made in midsummer. This growth is reflected in the later flowering and greater use of water during September and October. Continuously wilting the plants through the season affected the size of the plant, those under treatment 3 being the smallest and those under treatment 2 next to the smallest each year.

TABLE 14

Summary and Averages of Height of Plants, Seasons 1927 to 1930

Treatment	Height of plants, in inches				
	1927	1928	1929	1930	Average
1	65.0	53.0	38.2	35.6	48.0
2	49.5	45.0	32.0	30.8	39.3
3	42.7	40.0	31.8	27.9	35.6
4	46.5	48.0	38.0	32.5	41.2
5	55.0	53.0	45.0	39.5	48.1*

* The height of these plants was due to growth during the fall of the year, whereas normally it is made during midsummer.

On the light soil types such as the Delano sandy loams, although a high percentage of moisture may be maintained throughout the season, terminal growth ceases and the plant matures normally as the season advances.

Effect of Irrigation on Flowering.—Tables 15 and 16 give the results of the observations made on the dates on which the first flowers appeared, the dates of most intensive flowering and of opening of the first bolls, and on the flower counts each year under the different treatments.

The results given in table 15 show that the irrigation treatments as applied had no effect on the date of beginning of flowering. When water was withheld during the first half of the season (treatment 5), the period of most intensive flowering was hastened from 1 to 2 weeks, in three out of the four years, the date of opening of the first bolls was advanced about 1 week in each of the years of record, and the flowering period was extended into the late summer, with a resulting heavy crop of immature green bolls.

Considering the number of flowers per plant produced under the different treatments, table 16 shows in every year but one (1927) the greatest number of flowers was produced under treatment 1 and the least number under treatment 3. A full moisture supply during the first half of the season (treatments 1 and 3) also produced the greatest number of flowers per plant during the 5-day period of most intensive flowering.

TABLE 15

SUMMARY OF DATES OF FLOWERING, MOST INTENSIVE FLOWERING, AND OPENING OF FIRST BOLLS; SEASONS 1927 TO 1930

Treatment	Dates of first flowers				Dates of most intensive flowering				Dates first bolls opened		
	1927	1928	1929	1930	1927	1928	1929	1930	1927	1928	1929
1	June 26	June 21	June 30	June 28	July 25–30	July 25–30	Aug. 9–14	Aug.14–19	Sept. 1	Aug. 21	Aug. 20
2	June 26	June 20	June 29	June 30	July 20–25	July 15–20	July 20–25	July 20–25	Aug. 25	Aug. 17	Aug. 16
3	June 25	June 20	July 1	June 29	July 25–30	July 10–15	July 20–25	July 20–25	Aug. 24	Aug. 13	Aug. 13
4	June 26	June 21	June 30	June 30	July 20–25	July 25–30	July 30–Aug. 4	July 20–25	Aug. 28	Aug. 13	Aug. 13
5	June 26	June 20	June 29	June 29	July 25–30	July 10–15	July 20–25	July 20–25	Aug. 24	Aug. 14	Aug. 14

TABLE 16

Summary and Averages of Flower Counts; Seasons 1927 to 1930

Treatment	Number of flowers per plant					Number of flowers per plant during 5-day period of most intensive flowering				
	1927	1928	1929	1930	Average	1927	1928	1929	1930	Average
1	31.7	44.7	48.3	42.4	41.8	5.89	8.70	7.53	5.28	6.85
2	28.8	37.5	26.0	27.9	30.5	5.44	6.53	3.44	4.05	4.89
3	32.4	30.2	23.3	20.9	26.7	6.52	7.52	4.16	4.17	5.59
4	26.9	39.5	36.2	33.1	33.9	5.56	9.06	7.00	4.82	6.61
5	26.4	33.2	29.8	27.9	29.3	5.13	7.39	4.29	4.36	5.29

Effect of Irrigation on Shedding and Number of Bolls.—The percentage of shedding and number of bolls per plant produced under each of the treatments each year is given in table 17. Table 18 shows the percentage of five-lock bolls each season and the average weights of four and five-lock bolls under each of the treatments.

TABLE 17

Summary and Averages of Boll and Shedding Counts, Seasons 1927 to 1930

Treatment	Per cent shedding					Number of bolls per plant				
	1927	1928	1929	1930	Average	1927	1928	1929	1930	Average
1	85.7	68.5	70.7	77.8	75.7	20.2	22.4	17.2	15.9	18.9
2	90.1	70.0	66.9	77.8	76.2	13.9	20.6	14.1	13.7	15.6
3	92.9	76.0	75.5	84.7	82.3	10.6	19.7	11.1	9.0	12.6
4	90.0	76.0	75.0	80.5	80.4	12.5	18.6	13.8	14.0	14.7
5	90.8	72.0	75.9	81.5	80.0	14.8	23.7	17.9	15.7	18.0*

* Although this treatment shows a high average number of bolls per plant, a count at the end of the 1930 season showed 53 per cent of immature green bolls as compared with 7 per cent under treatment 1.

TABLE 18

Summary and Averages of Percentages of Five-Lock Bolls and Comparative Weights of Four and Five-Lock Bolls; Seasons 1927 to 1930

Treatment	Percentage of five-lock bolls					Weight of ten bolls, grams			
						Seed cotton		Seed	
	1927	1928	1929	1930	Average	4-lock bolls	5-lock bolls	4-lock bolls	5-lock bolls
1	80.0	89.0	82.4	81.2	83.1	72.1	94.0	45.4	60.5
2	75.9	80.0	67.1	67.7	72.6	65.7	89.2	41.5	57.4
3	75.6	56.0	74.0	70.0	68.9	67.6	80.2	43.1	52.4
4	74.9	72.0	75.6	74.4	74.2	65.5	83.7	41.4	53.3
5	75.8	62.0	71.1	70.0	74.4	65.5	85.7	40.9	54.8

Over the four-year period the highest percentage of shedding was in the 9 A.M. wilt (treatment 3), and the lowest percentage in the constantly moist plots (treatment 1). There was, however, but little difference between the latter and the 4 P.M. wilt.

As an average, the greatest number of bolls was produced under treatment 1, the number being slightly greater than that produced under treatment 5. The more intensive flowering later in the season under treatment 5 resulted in the production of a high percentage of immature, green bolls. A count at the end of the season of 1930 showed 7 per cent of green bolls on the plants under treatment 1 as compared with 53 per cent under treatment 5. Each year the 9 A.M. wilt plots produced the least number of bolls, averaging two-thirds of the number produced under treatment 1.

As shown in table 18 each year the highest percentage of five-lock bolls was found under treatment 1, and over the four-year period the lowest percentage was found under treatment 3. There is no consistency in the relation of five-lock to four-lock bolls in the remaining treatments.

TABLE 19

SUMMARY OF LENGTH OF STAPLE, LINT INDEX, AND UNIFORMITY, SEASONS 1927, 1928, AND 1930*

Treatment	Length of staple, inches			Lint index†		Uniformity		
	1927	1928	1930	1927	1930	1927	1928	1930
1	1⅛ to 1 3/16	1 3/32 to 1⅛	1⅛ to 1 5/32	8.51	8.85	Regular	Regular	Regular
2	1⅛	1 1/16 to 1⅛	1 3/32 to 1⅛	8.48	8.40	Slightly irregular	Regular	Irregular to regular
3	1 1/16 to 1⅛	1 1/16 to 1⅛	1⅛	8.48	7.70	Irregular, wasty	Regular	Irregular to regular
4	1⅛	1 1/16 to 1⅛	1 3/32 to 1⅛	7.77	8.07	Regular	Regular	Slightly irregular to regular
5	1⅛	15/16	1 3/32 to 1⅛	8.11	8.35	Regular	Regular	Regular

* Classification made by Division of Cotton Marketing, U. S. Dept. Agr. Bureau of Agricultural Economics.

† Average of an equal number of four and five-lock bolls.

Effect of Irrigation on Length of Fiber and Lint Index.—Table 19 is a summary showing the effects of the different irrigation treatments on the length of staple, lint index, and uniformity.

The differences in the staple produced under the different treatments, although small, are significant. Each year the length of fiber

was greatest under treatment 1, while that under treatment 5 averaged the least. No significant differences in staple were produced, however, in treatments 2, 3, and 4. During the two years in which measurements of the lint index were obtained, treatments 1 and 2 showed the highest values, while in treatments 3, 4, and 5 the results showed no consistent trend.

Effect of Irrigation on Yields.—The average yields of seed cotton per plant and the estimated yields of seed cotton and lint per acre produced each year under the different treatments carried through the four-year period are given in table 20. The average yields shown in this table were obtained each year from at least 1,000 plants under treatments 1, 2, and 3, and from 500 plants under treatments 4 and 5. The yields of lint in pounds per acre obtained in 1930 from the plots under treatments 1A and 1AA were 717 and 943, respectively, as compared to 930 pounds per acre produced under treatment 1.

Each year the largest yield was obtained with moisture available throughout the season, and the smallest yield came from the 9 A.M. wilt plots. Treatment 1 yielded 35 per cent more cotton than treatment 2, 48 per cent more than treatment 4, 63 per cent more than treatment 5, and 71 per cent more than treatment 3. In 1930, in the added treatment in which water was not applied until the foliage changed color, the yield was 23 per cent less than that obtained with available moisture continuously present.

Disregarding the possible differences in quality of cotton produced under the different treatments, and on the basis of a price of 10 cents a pound, the estimated gross returns under treatment 1 would be $103 an acre as compared to $76 under treatment 2, $60 under treatment 3, $70 under treatment 4, and $62 under treatment 5.

USE OF WATER AND YIELDS OF COTTON GROWN IN TANKS

Purpose of Experiment.—The purpose of this experiment was to duplicate in tanks the three principal irrigation treatments (Nos. 1, 2, and 3) used in the plot experiments that have been described. These treatments dealt with the total seasonal use of water, the rates of use of water, and the responses in growth and yields of cotton under different soil-moisture conditions.

In addition to twelve tanks thus used, six "water-table" tanks were installed in which a three-year study was made of the use of water, the growth, and the yields of cotton with a water table held at a uniform depth of 30 inches below the surface.

TABLE 20

SUMMARY AND AVERAGES OF YIELDS OF SEED COTTON PER PLANT, AND ESTIMATED YIELDS OF SEED COTTON AND LINT PER ACRE

Treatment	Yields of seed cotton, pounds per plot*					Estimated yields of seed cotton, pounds per acre†					Estimated yields of lint, pounds per acre‡						Comparative yields¶
	1927	1928	1929	1930	Average	1927	1928	1929	1930	Average	1927	1928	1929	1930	Average	Bales (500 pounds per acre)	
1	46.1	72.0	55.0	50.2	55.8	2,560	4,000	3,060	2,790	3,100	853	1,333	1,020	930	1,034	2.06	1.71
2	37.4	60.0	37.1	30.9	41.4	2,080	3,330	2,060	1,720	2,300	693	1,110	687	573	766	1.53	1.27
3	31.7	46.8	25.9	25.7	32.6	1,760	2,600	1,440	1,430	1,810	587	867	480	477	603	1.20	1.00
4	34.5	49.0	35.7	31.3	37.6	1,920	2,720	1,980	1,740	2,090	640	907	660	580	697	1.39	1.16
5	32.8	46.6	27.7	28.8	34.0	1,820	2,590	1,540	1,600	1,890	607	863	513	533	620	1.26	1.05

* Based on 180 plants in 1927 and 1928 and on 100 plants in 1929 and 1930.

† On basis of 10,000 plants per acre.

‡ Based on lint percentage of 33⅓.

¶ Obtained by giving treatment 3 a value of 1.00.

Description of Tanks and Equipment.—The twelve tanks used in duplicating the field trials were made of heavy galvanized iron, 27 inches in diameter and with an inside depth of 64 inches. The sides of the tanks extended several inches below the bottoms, which were fitted with a drainage faucet of small diameter. When filled to within 4 inches of the top, each tank contained 20 cubic feet of soil, the surface area being comparable with the area occupied by a single plant in the field.

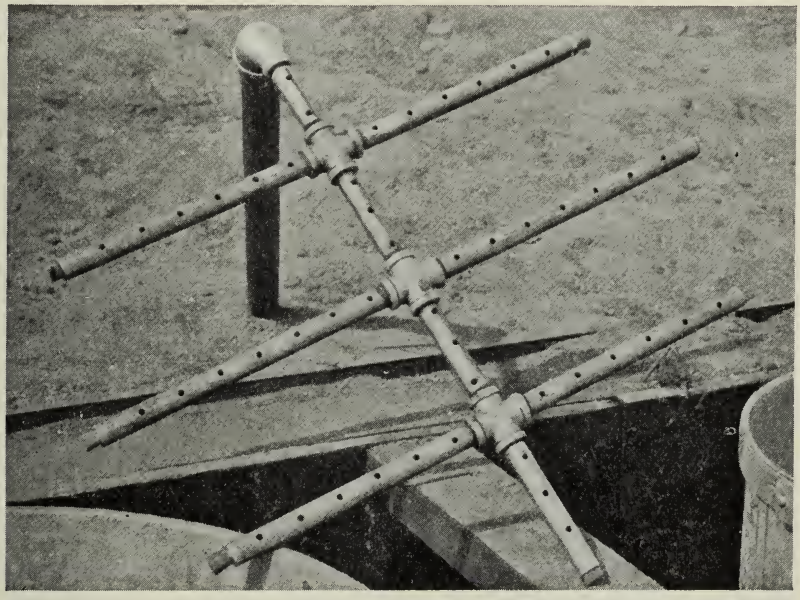


Fig. 12.—Perforated pipe used in tank experiments for applying irrigation water 6 inches below the soil surface.

The tanks were installed in a trench 54 feet long, 64 inches deep, and 30 inches wide, the natural soil being removed in 6-inch layers and, after air-drying, being replaced in the tanks as nearly as possible in its original condition, both as to compactness and depth. A wire screen and 4 inches of fine gravel were placed in the bottom of each tank to facilitate drainage of excess water from the soil. The same weight of air-dry soil was placed in each tank, and sufficient water was added to bring the soil to its field capacity.

In order to reduce evaporation losses from the soil surface and to aid in uniform water distribution, a network of ½-inch perforated pipe (fig. 12) connected with a 2-inch standpipe was placed at a depth of 6 inches below the soil surface in each tank. All water was applied

through these subsurface systems. During 1928 a layer of heavy tar paper was placed in the soil mulch 2 inches below the surface to prevent possible loss by evaporation. In 1929 and 1930 this paper was replaced with wall board cut to fit the circumference of the tank and placed on the soil surface.

The six water-table tanks, 27 inches in diameter and 60 inches deep, were perforated in the bottom and for about 1 foot up the sides. They were then jacketed to within 18 inches of the top by a larger tank which served as a reservoir for maintaining the water level in the inner tank. A ½-inch perforated pipe placed in the center of each tank was used in obtaining readings of underground water levels.

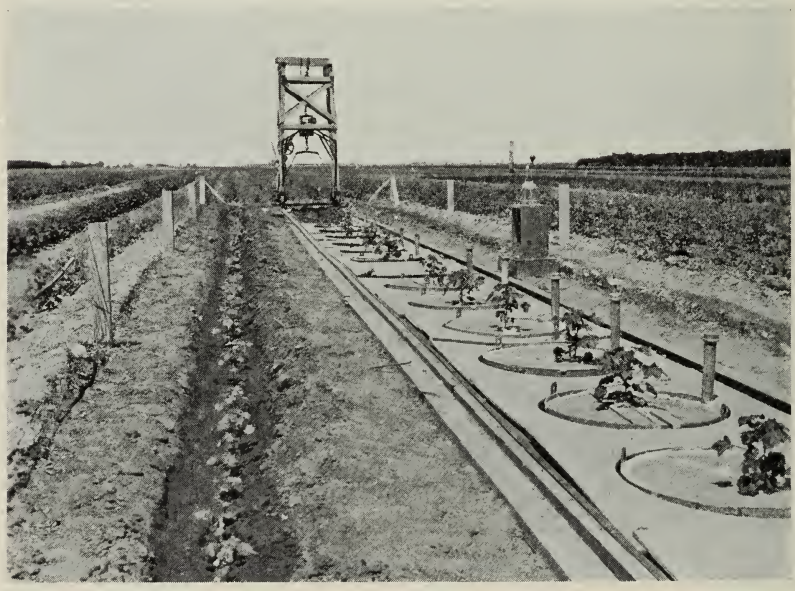


Fig. 13.—Tank yard, showing method of covering tanks, derrick used in weighing tanks, atmometers, and hedge of cotton grown around trench.

Losses were obtained by weighing with a 3,000-pound capacity suspension scale hung from a movable derrick centered over the trench in which the tanks were installed. Figure 13 is a general view of the tank yard, showing tanks, derrick, and lifting device.

Irrigation Treatments.—Treatments 1, 2, and 3 as applied to the field plots were duplicated in the tanks as follows:

Treatment 1 (four tanks): Irrigation water added when the soil moisture content in each tank was reduced to 7 per cent (about halfway between the field capacity of 11 per cent and the permanent wilting percentage of 3.5).

Treatment 2 (four tanks) : Irrigation water added when the plants wilted at 4 P.M.

Treatment 3 (four tanks) : Irrigation water added when the plants wilted at 9 A.M.

Procedure.—At the time the tanks were filled, a number of soil samples were taken from each foot depth of soil; and from these the dry weight of soil in each tank was obtained. Occasional soil samples taken through each season substantiated the correctness of these determinations.

After the first irrigation, in which more than enough water was added to bring the soil to field capacity, it was found that the sandy loam soil overlying the layer of gravel would not drain, the soil immediately above the gravel remaining in a saturated condition in all tanks until the excess water was removed by the roots of the cotton plants penetrating it. Similar observations have been made in the field, where fine sand or sandy loam soils have been found to be saturated immediately above a layer of coarse gravel. After the first irrigation, care was taken not to add more than the quantity of water needed to bring the soil to its field capacity.

Planting in the tanks was done at the same time as planting in the field plots. Twelve seeds were placed in each tank; and, at the time the field plots were chopped, only the most thrifty plant was left in each tank. At this time the tar-paper or wall-board covering previously mentioned was put in place. The space between the stalk of the plant and the edge of the hole through which it grew was snugly packed with cotton.

Systematic weighing was started at the time of thinning and continued through the season.

Daily flower counts were made on all plants through the flowering period, and at the end of the season the weight of seed cotton produced from each plant was obtained.

Use of Water by Cotton Grown in Tanks.—The daily use of water and the equivalent use in 30 days by cotton plants grown under treatments 1, 2, and 3 during the season of 1928 are given in table 21. The corresponding seasonal use of water is shown in figures 14, 15, and 16, and table 22 gives the total seasonal use of water under the different treatments for each of the three years.

TABLE 21

AVERAGE DAILY USE OF WATER AND EQUIVALENT USE OF WATER IN 30 DAYS BY COTTON PLANTS GROWING IN TANKS UNDER IRRIGATION, TREATMENTS 1, 2, AND 3; SEASON OF 1928

Dates	Treatment 1				Treatment 2				Treatment 3			
	Number of days	Total use, average of four tanks	Average daily use	Equivalent use in 30 days	Number of days	Total use, average of four tanks	Average daily use	Equivalent use in 30 days	Number of days	Total use, average of four tanks	Average daily use	Equivalent use in 30 days
		pounds	*pounds*	*acre-inches per acre*		*pounds*	*pounds*	*acre-inches per acre*		*pounds*	*pounds*	*acre-inches per acre*
June 6 to June 21	15	22.8	1.52	2.2	15	19.0	1.27	1.82	15	21.0	1.40	2.02
June 21 to June 29	8	48.2	6.02	8.6	8	49.8	6.22	8.95	8	45.4	5.67	8.15
June 29 to July 13	14	125.0	8.93	13.0	14	87.9	6.28	9.02	14	82.1	5.86	8.44
July 13 to July 24	11	176.0	16.00	23.0	11	115.3	10.48	15.10	11	76.4	6.95	12.90
July 24 to July 31	7	112.5	16.10	23.1	7	70.7	10.10	14.60	7	57.4	8.20	11.80
July 31 to August 7	7	97.0	14.10	20.3	7	63.0	9.00	12.92	7	58.9	8.42	12.10
August 7 to August 14	7	113.0	16.10	23.1	7	63.0	9.00	12.92	7	44.8	6.40	9.22
August 14 to August 21	7	99.2	14.10	20.3	7	63.0	9.00	12.92	7	60.7	8.67	12.50
August 21 to August 28	7	70.0	10.00	14.4	7	52.8	7.55	10.90	7	46.5	6.65	9.60
August 28 to September 4	7	56.0	8.00	11.5	7	48.6	6.95	10.00	7	35.9	5.13	7.40
September 4 to September 11	7	44.1	6.30	9.1	7	29.5	4.22	6.10	7	25.7	3.68	5.40
September 11 to September 18	7	37.8	5.40	7.8	7	28.6	4.08	5.90	7	29.0	4.15	6.00
September 18 to October 1	12	52.8	4.40	6.3	12	60.0	5.00	7.20	12	52.6	4.38	6.30
October 1 to October 19	18	48.6	2.70	3.9	18	42.3	2.35	3.40	18	38.7	2.15	3.10
October 19 to November 1	12	21.6	1.80	2.6	12	15.8	1.32	1.90	12	10.2	0.85	1.20
Total	146	1,124.6			146	809.3			146	685.3		

TABLE 22

Total Water Used in Acre-Inches Per Acre by Cotton Plants Growing in Tanks Under Treatments 1, 2, and 3; Seasons of 1928, 1929, and 1930

Treatment	Tank No.	Total use of water, acre-inches per acre		
		1928	1929	1930
1	9	52.2	44.37	25.65
	12	51.7	45.39	24.50
	15	51.8	49.56	22.82
	18	.....	44.60	22.41
	Average	51.90	45.98	23.85
2	8	38.0	28.82	22.06
	11	36.2	34.58	23.41
	14	37.6	33.73	18.97
	17	38.6	34.12	19.29
	Average	37.60	32.81	21.33
3	7	35.6	30.52	20.62
	10	32.9	22.80	21.43
	13	30.6	33.61	18.78
	16	28.8	30.67	19.29
	Average	31.90	29.40	20.03

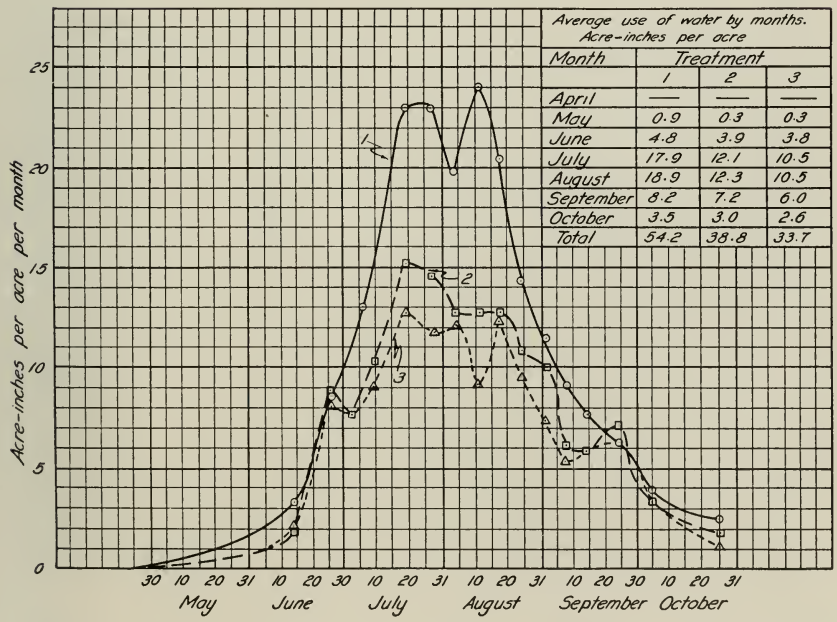


Figure 14.—Average seasonal use of water in acre-inches per acre per month by cotton plants grown in tanks under treatments 1, 2, and 3, season of 1928.

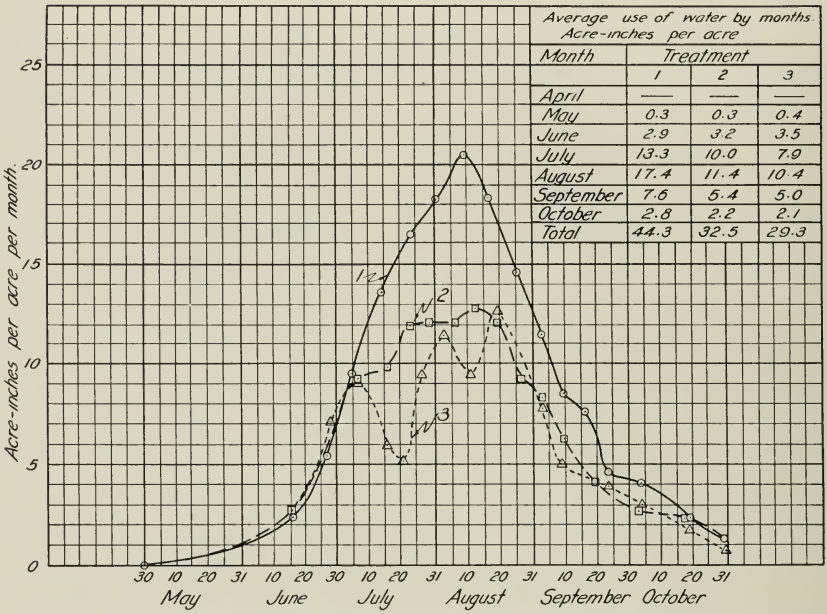


Fig. 15.—Average seasonal use of water in acre-inches per acre per month by cotton plants grown in tanks under treatments 1, 2, and 3, season of 1929.

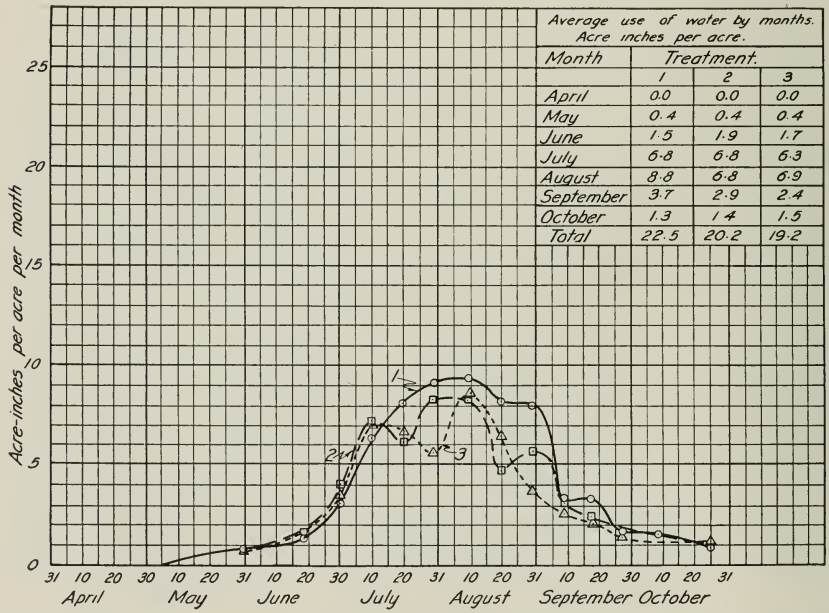


Fig. 16.—Average seasonal use of water in acre-inches per acre per month by cotton plants grown in tanks under treatments 1, 2, and 3, season of 1930.

A comparison of the size of plants grown in the tanks with those grown in the field plots under similar irrigation treatments, showed that smaller plants were produced in the tanks each year than were obtained in the plots. These smaller plants, however, used from 40 to 53 per cent more water than the plants growing in the field. This increased use of water might be explained by the probable root concentration in the limited soil mass of the tanks, a higher soil temperature in the tanks, and the higher temperatures and lower humidities surrounding the individual plants in the tanks.

It was also observed that each year the plants in the tanks were smaller than those produced under the same irrigation treatment the year before. The effect of these smaller plants is shown in the decreasing use of water each year (table 22).

By comparing figures 7, 8, and 9 with figures 14, 15, and 16 it will be seen that the general shape of the seasonal-use-of-water curves are the same for the tanks as for the field plots. Under the same irrigation treatment the peak use of water came at the same time of the season, although in the tanks there was a more rapid decrease in the rate after the peak had been reached.

During the three years in which cotton was grown in tanks in which a 30-inch water table was maintained, no variation was made in the treatment. Each year a surface irrigation of sufficient depth to moisten thoroughly the entire soil mass was applied at the time of planting. For the remainder of the season the water table was maintained at a depth of 30 inches below the soil surface. Weekly losses were obtained by weighing the tanks, and the proper water level was maintained by adding the required amount of water to the outer reservoir. From the beginning, the capillary rise from the water table was evidently insufficient to meet the needs of the plants; and an examination of the soil showed that after July 1 the top 1½ feet was at the permanent wilting percentage, while the foot of soil immediately above the water table ranged from a moist to a saturated condition.

Table 23 shows the average daily use and equivalent use of water in 30 days as obtained from the six water-table tanks during 1929. The results for 1928 and 1930 were similar. Table 26 shows the total seasonal use of water from these tanks each year.

The seasonal use of water as shown in table 24 averages 11 acre-inches per acre as compared with an average use of 40 acre-inches in the tanks under treatment 1. The plants appeared to grow normally until the latter part of June or early in July, after which growth stopped and the plants took on a drought-stricken appearance.

TABLE 23

AVERAGE DAILY USE AND EQUIVALENT USE OF WATER IN 30 DAYS BY COTTON PLANTS IN TANKS WITH THE WATER TABLE AT A DEPTH OF 30 INCHES; SEASON OF 1929

Date	Number of days	Average of six tanks	Average daily use	Equivalent use in 30 days
		pounds	*pounds*	*acre-inches per acre*
June 5 to June 24	19	13.7	0.72	1.0
June 25 to July 1	7	20.2	2.90	4.1
July 2 to July 5	4	19.2	4.80	6.9
July 6 to July 9	5	22.3	4.45	6.4
July 10 to July 12	3	13.7	4.55	6.6
July 13 to July 16	4	14.7	3.70	5.3
July 17 to July 19	3	14.2	4.70	6.8
July 20 to July 23	4	16.0	4.00	5.8
July 24 to July 26	3	11.3	3.75	5.4
July 27 to July 30	4	10.2	2.55	3.7
July 31 to August 2	3	8.2	2.75	3.9
August 3 to August 6	4	10.5	2.60	3.8
August 7 to August 9	3	8.5	2.80	4.1
August 10 to August 13	4	13.0	3.25	4.6
August 14 to August 16	3	6.8	3.20	3.3
August 17 to August 20	4	10.5	2.60	3.8
August 21 to August 23	3	8.2	2.70	3.9
August 24 to August 27	4	5.5	1.40	2.0
August 28 to August 30	3	5.0	1.70	2.4
August 31 to September 3	4	5.8	1.45	2.1
September 4 to September 6	3	2.7	0.90	1.3
September 7 to September 13	7	4.2	0.60	0.9
September 14 to September 16	3	3.7	1.25	1.8
September 17 to September 20	4	4.7	1.20	1.7
September 21 to September 24	4	3.7	0.90	1.3
September 25 to September 27	3	4.5	1.50	2.2
September 28 to October 11	14	9.3	0.70	0.9
October 12 to October 26	15	10.7	0.70	1.0
October 27 to November 2	7	2.0	0.30	0.4
Total	151	283.0	.....	.....

TABLE 24

TOTAL USE OF WATER BY COTTON PLANTS GROWING WITH WATER TABLE 30 INCHES BELOW SURFACE; SEASONS OF 1928, 1929, AND 1930

Year	Period covered in study	Average use of water by all tanks
		acre-inches per acre
1928	June 9 to August 31*	10.61
1929	June 5 to November 2	13.59
1930	June 25 to November 5	8.69

* Growth stopped and weighing discontinued.

Flowering Records and Yields of Cotton Grown in Tanks.—The number of flowers produced in 5-day intervals by cotton plants growing in tanks under the different irrigation treatments is shown in tables 25 and 26, and the corresponding yields in seed cotton from the different tanks is given in table 27. In table 28 a comparison is made of the quantities of water used and yields of cotton grown in field plots and tanks under the same irrigation treatments.

TABLE 25

Number of Flowers Produced During 5-Day Intervals on Four Cotton Plants Growing in Tanks Under Each of Three Irrigation Treatments; Seasons of 1928, 1929, and 1930

Date	Treatment 1			Treatment 2			Treatment 3		
	1928	1929	1930	1928	1929	1930	1928	1929	1930
June 19 to June 24	4	....	....	3	....	....	5	....	....
June 24 to June 29	10	....	....	9	1	....	7	1	....
June 29 to July 4	11	7	1	11	6	....	12	9	1
July 4 to July 9	12	14	3	18	10	5	10	10	4
July 9 to July 14	28	26	7	24	27	17	32	24	11
July 14 to July 19	64	27	19	48	32	20	42	36	13
July 19 to July 24	12	46	21	70	30	20	27	36	30
July 24 to July 29	78	47	29	55	43	33	38	39	33
July 29 to Aug. 3	85	58	28	9	42	28	10	14	29
Aug. 3 to Aug. 8	24	57	33	3	17	23	2	....	21
Aug. 8 to Aug. 13	24	71	11	1	10	3	9	....	2
Aug. 13 to Aug. 18	16	40	14	2	....	3	3	....	....
Aug. 18 to Aug. 23	1	9	4	....	....	....	....	....	....
Aug. 23 to Aug. 28	....	....	1	....	....	....	....	....	....
Total	369	402	171	253	218	152	197	169	144

Comparison of the number of flowers produced by each plant shows that on the average about 75 per cent more flowers were produced in the tanks than were produced under the same irrigation treatment in the field plots. The peak of the flowering period was reached at about the same time, although in the tanks there was a rather sudden drop in the production of flowers after the peak had been reached, together with an earlier cessation of flowering. The flowering of the plants in the water-table tanks was characterized by early flowering, by the very limited number of flowers produced, and by abrupt cessation of flowering in midsummer.

The yield records as given in tables 29 and 30 show that in each treatment there is a decrease in yield each year, accompanied by a corresponding decrease in the use of water. As was expected, a materially increased yield per plant was obtained from plants grown in tanks

over that grown in the field. This increase amounted to an average of 45 per cent and was accompanied by a 47.5 per cent increase in the use of water.

In the field plots an average of 2,120 pounds of water was used in producing 1 pound of seed cotton while in the tanks the average was 2,090 pounds. This ratio was approximately the same for each of the treatments.

TABLE 26

NUMBER OF FLOWERS PRODUCED DURING 5-DAY INTERVALS ON SIX COTTON PLANTS GROWING IN WATER-TABLE TANKS; SEASONS OF 1928, 1929, AND 1930

Date	Year		
	1928	1929	1930
June 19 to June 24	8	2	....
June 24 to June 29	9	5	....
June 29 to July 4	14	9	....
July 4 to July 9	14	12	....
July 9 to July 14	28	31	....
July 14 to July 19	37	34	....
July 19 to July 24	16	49	6*
July 24 to July 29	1	33	12
July 29 to Aug. 3	....	8	24
Aug. 3 to Aug. 8	....	....	28
Aug. 8 to Aug. 13	....	....	17
Aug. 13 to Aug. 18	....	....	18
Aug. 18 to Aug. 23	....	....	1
Total	127	183	106

* Flowering started later because second planting had to be made on May 3.

CONCLUSIONS

The top 5 feet of the Delano sandy loams, as found at the Cotton Field Station at Shafter, has an apparent specific gravity of 1.50, an average field capacity of 11.0 per cent, and a permanent wilting percentage of 3.5.

When this soil is at the permanent wilting percentage, 1.35 inches of rainfall or irrigation water is required to bring one foot (in depth) of soil to its field capacity; or each inch (in depth) of water applied will penetrate to a depth of 9 inches.

When grown with an available moisture supply continuously present throughout the season to a depth of 5 feet, a full stand of cotton on the Delano sandy loams at the Cotton Field Station used an average of 29.5 acre-inches per acre.

On the basis of a reasonable efficiency in irrigation (70 to 75 per cent), from 30 to 36 acre-inches per acre of irrigation water will be

required during the growing season of the crop, in addition to a pre-season irrigation of 6 to 8-acre-inches per acre. The irrigation requirement during each month in acre-inches per acre will be about as follows: March or April, 6 to 8; June, 4; July, 9; August, 11; September, 7; and October, 3.

TABLE 27

Yield of Seed Cotton Grown in Tanks Under Different Irrigation Treatments; Seasons of 1928, 1929, and 1930

Year	Yield in grams from individual tanks					Yield, in pounds per plant
	Treatment 1					
	Tank No. 9	Tank No. 12	Tank No. 15	Tank No. 18	Average	Average
1928	210.0	219.6	316.0	265.0	252.6	0.557
1929	232.5	198.8	222.1	209.9	215.8	0.476
1930	134.0	123.0	104.8	119.0	120.2	0.265
Average	192.2	180.5	214.3	198.0	196.2	0.433
	Treatment 2					
	Tank No. 8	Tank No. 11	Tank No. 14	Tank No. 17	Average	Average
1928	186.2	175.8	236.3	189.5	196.9	0.434
1929	139.5	151.7	164.2	170.0	156.3	0.345
1930	100.0	106.1	90.6	133.3	107.5	0.237
Average	141.9	144.5	163.7	164.3	153.5	0.339
	Treatment 3					
	Tank No. 7	Tank No. 10	Tank No. 13	Tank No. 16	Average	Average
1928	153.2	131.0	153.0	161.7	149.7	0.330
1929	129.2	139.9	185.5	139.7	148.6	0.328
1930	106.9	116.0	65.8	106.4	98.8	0.218
Average	129.8	129.0	134.8	135.9	132.4	0.292
	With water table at 30 inches					
	Tank No. 1	Tank No. 2	Tank No. 3	Tank No. 4	Tank No. 5	Tank No. 6	Average	Average
1928	30.3	38.8	33.0	33.5	28.2	32.7	32.7	0.072
1929	24.1	40.0	27.1	26.5	42.7	23.7	30.7	0.067
1930	25.5	19.3	.....	19.7	20.4	17.9	20.6	0.045
Average	26.6	32.7	30.0	26.6	30.4	24.8	28.0	0.061

There is but little difference in the seasonal use of water when the plants are allowed to wilt at 4 p.m. and at 9 a.m. The amounts of water used under these treatments averaged two-thirds of that used when moisture was continuously available.

On the average there is not a significant difference in the quantities used when water was withheld early or late in the season (treatments 4 and 5). Under these treatments the use was 80 per cent of that when moisture was continuously available.

Continuously available moisture, as under treatment 1, produced the largest number of flowers per plant, the lowest percentage of shedding, the largest number of bolls per plant, the highest percentage of five-lock bolls, the longest staple, the highest lint index, and the largest yields. Treatment 3 (9 A.M. wilt) consistently produced the least number of flowers, the highest percentage of shedding, the least number of bolls, the lowest percentage of five-lock bolls, and the lowest yields. The results obtained under treatment 2 (4 P.M. wilt) were consistently between those obtained under treatments 1 and 3.

TABLE 28

COMPARISON OF QUANTITIES OF WATER USED AND YIELDS OF COTTON GROWN IN IN FIELD PLOTS AND TANKS UNDER THE SAME IRRIGATION TREATMENTS; SEASONS OF 1928, 1929, AND 1930

Experiment	Treatment No.			Treatment No.		
	1	2	3	1	2	3
	Average seasonal use of water, acre-inches per acre			Average yields, pounds of seed cotton per plant		
Field plots	29.5	20.6	18.9	0.328	0.237	0.182
Tanks	40.3	30.5	27.4	0.433	0.339	0.292
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Increase, tanks over field plots	39.4	50.2	53.0	32.0	43.0	60.4

The effects of treatment 5, in which the plants were subjected to stress by withholding water during the first half of the season, and given an abundant supply during the last half, are particularly reflected in the slightly larger size of the plants, the shorter staple, the high percentage of green, immature bolls at harvest, and the comparatively low yields. The greater height of plants obtained under this treatment followed expectation by producing the heaviest growth in the fall of the year, whereas normally it is made during midsummer. The low yield resulted principally from the higher percentage of immature bolls at harvest.

Treatment 4 was consistently better than treatment 5 in yields, with but small difference in flowering, shedding, percentage of five-lock bolls, and weight of cotton or seed per boll.

Treatment 1A (1930 only), in which water was withheld until the plants showed their first indication of soil-moisture depletion by their change in color, was intermediate between treatments 1 and 2 in the amounts of water used during the season, the number of flowers produced, average height of plants, percentage of five-lock bolls, lint index, and yield. The yields resulting from this one year's trial were at the rate of 717 pounds of lint per acre, as compared with 930 pounds produced the same season under treatment 1. Although no conclusions can be drawn from one year's trial, the indications are that the withholding of water until the plants change color, prior to wilting, produces a decrease in yield.

The yields obtained from one year's trial with treatment 1AA indicate that in the Delano sandy loam soil, as found at the Cotton Field Station, the average soil moisture content of the top 5 feet of soil could be reduced to at least 6 per cent without diminishing the yields.

In applying these results to field practice, especially where large acreages are under irrigation, it should be remembered that, if the beginning of an irrigation is delayed until the soil-moisture content approaches the permanent wilting percentage, much of the acreage may be badly wilted before the irrigation is completed.

When cotton plants were grown in tanks 5 feet deep and with an area (4 sq. ft.) comparable to that occupied by a plant in the field, each year smaller plants were produced than were obtained with the same irrigation treatment in the field. The smaller plants, however, used 47 per cent more water than the plants growing in the field, and produced an average of 73 per cent more flowers and 45 per cent more seed cotton.

The general shape of the use-of-water curves is the same for the tanks as for the field plots; the peak use of water came at the same time of the season, although in the tanks there was a more rapid decrease in the use of water after the peak had been reached.

The tanks with a water table maintained at 30 inches through the season, each year produced early-maturing plants of small size, with a poor yield of seed cotton and lint. Under these conditions the plants appeared to grow normally until the latter part of June or early in July, after which growth stopped and the plants took on a drought-stricken appearance.

In this soil type there is every reason to believe that profitable cotton production cannot be obtained where the only source of water supply for the crop is a water table 30 inches or more below the surface.

The results herein presented were obtained on a light soil type. Although this soil is representative of that upon which the larger part of the acreage in the San Joaquin Valley is grown, the results obtained may not be applicable to the heavier soil types. Beginning in 1931 field studies of the use of water by cotton were started on the heavy soil (Panoche clay adobe) in the Firebaugh-Los Banos area.

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